3 HYDROGEOLOGIC SETTING

The following sections briefly describe the hydrogeologic setting of the Site at three scales. The regional scale places the site in the context of the groundwater basin. The Site vicinity scale provides a context for the site that has been developed based on data collected in the immediate vicinity of the Site by large investigations at adjacent sites. The Site scale is a compilation of Site data, some of which has not been previously compiled.

3.1 Regional Hydrogeology

The Site is located on a broad plain at an elevation of approximately 50 feet MSL. The DWR and USGS define this area as the Torrance Plain, a Pleistocene-age marine surface and a subdivision of the Coastal Plain of Los Angeles and Orange Counties. The ground surface in this area is generally flat with an eastward gradient of about 20 feet per mile (less than one-half percent). Surface drainage is generally toward the Dominguez Channel, about a mile to the east. The Dominguez Channel, in turn, flows southeastward toward the Los Angeles and Long Beach Harbors in San Pedro Bay.

3.1.1 Regional Hydrogeologic Units

The relationship among regional hydrostratigraphic units is best illustrated in the regional hydrogeologic cross sections that pass near the Site included in Appendix A. The surface sediments in this area are assigned to the Lakewood Formation (DWR, 1961), a unit defined to include essentially all of the upper Pleistocene sediments in the Los Angeles Coastal Plain area. The Lakewood Formation includes deposits of both marine and continental origin, representing stream transport and sedimentation along the Pleistocene marine plain. In the Site area, the Lakewood Formation includes the Bellflower Aquiclude, and the Gage Aquifer. The Semiperched Aquifer that is present regionally and has been discussed in previous hydrogeologic descriptions of the Site does not appear to be present in the Site Vicinity.

The Bellflower Aquiclude is described as a heterogeneous mixture of continental, marine, and wind-blown sediments, mainly consisting of clays with sandy and gravely lenses (DWR, 1961). The base of the Bellflower Aquiclude is about 100 feet below sea level (about 150 feet bgs) in the Site area. The Gage Aquifer is a water-bearing zone of fine to medium sand and gravel confined by the Bellflower Aquiclude. It is reported to be about 40 feet thick in the Site area and is described as being of secondary importance as a water source (DWR, 1961).

The Lakewood Formation is underlain by the Lower Pleistocene San Pedro Formation, which continues to about 1,000 feet in depth in the Site area. Major water-bearing zones within the San Pedro Formation are the Lynwood Aquifer and the Silverado Aquifer. These are reported to be at depths of about 300 and 500 feet, respectively, in the Site area (DWR, 1961). The Silverado is an important groundwater source in the Coastal Plain and is considered a source of drinking water (DWR, 1961).

3.1.2 Regional Groundwater Flow

Regional groundwater flow in the aquifers of West Coast Basin is generally from west to east. This flow direction is setup by a combination of groundwater injection through wells of the West Coast Basin Barrier Project located about four miles to the west of the Site and

active groundwater production in the Carson-Dominguez Area (Appendix A, Location Map of the West Coat Basin) to the east of the Site. The West Coast Basin Barrier Project was initiated in the 1960s and consists of approximately 150 injection wells located from the City of El Segundo on the north to the Palos Verdes Hills on the south. The barrier protects aquifers in the West Coast Basin from salt-water intrusion. Because salt water had entered the aquifers prior to the start of injection, the barrier isolated plumes of saline water in the Gage (2000-Foot Sand Aquifer), Silverado Aquifer and Lower San Pedro Aquifer (James M. Montgomery, 1992). These plumes are migrating eastward toward the production wells in the Dominguez pumping trough from which over 40 percent of the basin groundwater production is pumped. Management of the West Coast basin's groundwater resources since the 1960's has caused a general rise in water levels throughout most of the basin. This rise is illustrated in the representative hydrographs shown in Figure 3-1.

3.2 Hydrogeology of the Site Vicinity

Significant hydrogeologic investigations have been performed in the vicinity of the Site. Borehole/well completion logs are included in Appendix A for the Site and the former ILM site. The hydrogeologic units that are present in the Site vicinity are described to provide a context for understanding the hydrogeology of the Site. Groundwater flow in the Site Vicinity is also described.

3.2.1 Hydrogeologic Units and Cross Sections in the Site Vicinity

Over 200 groundwater monitoring wells have been installed in the Site vicinity. Borehole logs from these wells have been interpreted by others to refine the regional hydrostratigraphy. Dames & Moore (1998) and Hargis+Associates (1992) defined hydrostratigraphic units to describe conditions for the Del Amo Study Area and the Montrose site respectively. These units are compared to each other and the published regional hydrostratigraphy (Appendix B, Comparison of Stratigraphic Nomenclature). The hydrostratigraphic nomenclature developed by Dames & Moore (1998) has been adopted for the Site because:

1) The Del Amo Study Area hydrostratigraphic units recognize important subunits in the Bellflower Aquitard that are meaningful for hydrogeologic conditions at the Site and

2) The Del Amo nomenclature is being used by the US EPA for the Dual Site groundwater Operable Unit.

Three hydrogeologic cross-sections of the Site vicinity are included on Sheet 2. These cross sections are extended from cross-sections prepared for the Del Amo Study Area (Dames & Moore, 1998) by adding well log information from both the Site and the former ILM site. The primary information used to extend the cross sections was obtained from two deep boreholes (DB-1 and DB-2) drilled at the former ILM site (TRC, 1999).

The extended cross sections on Sheet 2 illustrate the relationships of the following primary hydrogeologic units at the Site and the adjacent sites:

- Upper Bellflower Aquitard (UBF)
- Middle Bellflower Aquitard (MBFB, MBFM, MBFC and MBFB/C)
- Lower Bellflower Aquitard (LBF)
- Gage Aquifer (GAGE)

- Gage-Lynwood Aquitard (GLA)
- Lynwood Aquifer (Lynwood)

The relatively fine-grained Upper Bellflower Aquitard is continuous across the area but thins to the northwest and is much thinner beneath the Site and the former ILM site than at former Montrose and former Del Amo sites. The Upper Bellflower Aquitard is comprised of laminated to massive yellowish brown muds with local sands and fossiliferous zones. The sands within the Upper Bellflower Aquitard are generally discontinuous but may extend laterally to more than 1000 feet. Groundwater water is present in the lower portion of UBF at the Del Amo Study Area, but is not present in the UBF beneath the Site.

Middle Bellflower Aquitard is a massive, light yellowish brown, fine to medium sand with local muddy zones. An extensive mud layer that is referred to as the Middle Bellflower Mud (MBFM) locally interrupts this sand. Where divided, the sand subunits are referred to as the B-Sand (MBFB) and C-Sand (MBFC). The Middle Bellflower Mud is discontinuous across the area and is comprised of laminated silts and layered silts and very fine sands. Deeper borings at the former ILM site and the Site (represented by P-22 in cross section DD-D-D', Sheet 2) do not always encounter fine-grained sediments of the Mud at the expected depths.

The fine-grained Lower Bellflower Aquitard appears to be continuous across the area. The LBF in the Site vicinity is comprised of laminated to massive mud and interbedded fine sands and muds. It ranges in thickness form 5 to 25 feet and separates the Bellflower sands from the underlying Gage Aquifer.

The Gage Aquifer in the Site vicinity is predominately sand and ranges in thickness from 40 to 78 feet. No monitoring wells are drilled into the Gage Aquifer at the Site.

The Gage-Lynwood Aquitard is similar to the Lower Bellflower Aquitard in the Site vicinity and consists of laminated to massive muds and interbedded fine sands and muds. The Gage-Lynwood Aquitard is estimated to be an average of 26 feet thick in the area and separates the Gage and the Lynwood aquifers.

The Lynwood Aquifer in the Site Vicinity is comprised of fine- to coarse-grained sands with local gravel beds. Very limited data are available for this unit. No wells are drilled into the Lynwood Aquifer at the Site.

3.2.2 Groundwater Flow in the Site Vicinity

Groundwater conditions at the Site are known from previous investigations and from the quarterly groundwater monitoring programs (Kennedy/Jenks, 1997b). Groundwater elevations have been measured at the Site since 1987 and samples from monitoring wells at the Site have been sampled and analyzed on a regular basis (usually quarterly) since 1992. Monitoring dates for the Site, the former ILM site and Del Amo Study Area are shown in Table 2-1. Table 3-1 summarizes the well construction details for Site monitoring wells. Table 3-2 summarizes water level data for the site. Groundwater elevation maps for various hydrogeologic units in the Site vicinity are shown on Sheets 3 through 6 to illustrate the direction of groundwater flow in the Site vicinity. These maps are composite maps that

include data measured during the period of September 1996 through January 1997and should be used accordingly.

Time-series groundwater contour maps for the Del Amo Study Area (Appendix B) illustrate that the directions of groundwater flow in individual hydrogeologic units have remained relatively consistent during the period of monitoring (1993 to 1996).

3.2.2.1 Shallow Groundwater System

The shallow groundwater system below the former Del Amo site is largely the fine-grained upper Bellflower Aquitard. Beneath the Site and the former ILM site, groundwater is present in the Middle Bellflower Aquitard. Groundwater elevations in the shallow groundwater system (Sheet 3) suggest a general southward direction of flow across the area. Local variability in this pattern includes:

1) An area of eastward flow along the western boundary of the former ILM site.

2) Radial flow around potentiometric highs near the south end of the former Del Amo site.

TRC attributes the potentiometric highs at western ILM site boundary to the presence of a fine-grained unit the near the water table. TRC does not explain this occurrence but seems to suggest that fine-grained unit near the water table may result a local perched condition in monitoring wells by raising the apparent water table several feet. The relationships shown in cross section DD-D-D' suggest that the fine-grained unit at 65 feet in DB-1 may be the Middle Bellflower Mud (Sheet 2.).

Groundwater mounding at the south end of former Del Amo site is inferred to be the result of local recharge in the fine-grained Upper Bellflower Aquifer. Dames & Moore (1997) note the occurrence of the mounds in the vicinity of the Del Amo Waste Pits but offers no further explanation.

3.2.2.2 Middle Bellflower B-Sand.

Groundwater elevations for the Middle Bellflower B-Sand are shown on Sheet 4. Beneath the Site and the former ILM site, groundwater is unconfined in the Middle Bellflower Aquitard and shallow well data were used to construct the contour map. Under much of the Del Amo Study Area, groundwater in the B-Sand is 'confined' below the Upper Bellflower Aquitard and contours are drawn using data from wells completed in the B-S. Groundwater elevations in the Upper Bellflower Aquitard suggest that the direction of flow is to the southeast.

3.2.2.3 Middle Bellflower C-Sand

Groundwater elevations for the Middle Bellflower C- Sand are shown on Sheet 5. At the Site and the former ILM site, water level data from the deep monitoring wells are used to construct the map. For the Del Amo Study Area, data from wells completed in the C-Sand are used to construct the map. The flow direction suggested by the map is to the south across much of the area. To the south, the flow direction is generally to the south and east.

3.2.2.4 Gage Aquifer

Groundwater elevations for the Gage Aquifer are shown on Sheet 6. Because there are no wells at the Site or the former ILM site that are completed in the Gage, contours are not shown in these areas of the map. Data from the Del Amo Study area suggest that the direction of groundwater flow in the Gage Aquifer is to the east-southeast.

3.2.3 Vertical Hydraulic Gradients

Vertical hydraulic gradients were estimated for the Del Amo Study Area using water levels from a large number of well pairs completed in various hydrostratigraphic units (Dames & Moore, 1998). A table of vertical gradient data for the Del Amo Study Area is included in Appendix B. Average vertical gradients are reported as follows:

- Water Table to B-Sand -0.0234 ft/ft
- B-Sand to C Sand -0.0027 ft/ft
- C-Sand t Gage Aquifer -0.0304 ft/ft
- Gage Aquifer to Lynwood Aquifer -0.187 ft/ft.

The negative values indicate that the gradients are vertically downward. Two of nine well pairs between the B-Sand and C- Sand were reported to have upward vertical gradients.

3.2.4 Aquifer Properties

Aquifer properties for the Site vicinity were characterized by performing slug test and pump tests on various wells in the Del Amo Study Area. Tables summarizing these test results are presented in Appendix D. Estimates of hydraulic conductivity and storativity obtained from these tests are within the normal ranges for the types of materials tested.

3.3 Hydrogeology of the Site

3.3.1 Hydrogeologic Units at the Site

The uppermost groundwater at the Site is the Middle Bellflower Aquiclude under water-table conditions at depths of 60 to 70 feet. The regional relationships shown in cross-sections AA-A-A' and DD-D-D' (Sheet 2) suggest that the Middle Bellflower Aquiclude consists of two fine-grained sands (B-Sand and C-Sand) separated by a finer-grained Mud. The locations of site-specific hydrogeologic cross sections are included in Figure 3-2 and seven cross sections are shown in Figures 3-3 through 3-8.

Monitoring wells at the Site are completed in two zones. Wells WCC-1S to WCC-12S, TMW-1 to TMW-16 and BL-1 to BL-6 are screened in the interval between 60 and 90 feet bgs. WCC-3D and WCC-1D were completed with screens in the interval from 120 to 140 feet bgs (Woodward-Clyde Consultants, 1990). Both of the deeper wells were located in close proximity to each other in the northeast portion of the Site.

The deeper wells encountered several thin layers of clayey silt between 60 and 80 feet bgs but no well-developed fine-grained unit. Thicker clay units (5 to 17 feet thick) were encountered below 100 feet bgs. Nine of the shallower wells encountered fine grain soils between 40 and 65 feet, often above the water table at 65 feet bgs.

Locally, the Middle Bellflower Mud is absent, is present at or near the current water table, or is poorly developed in the Site vicinity. Therefore, the shallow groundwater monitoring wells appear to be completed either the B-Sand or the combined B/C-Sand. The deeper wells appear to be completed in the C-Sand, just above the Lower Bellflower Aquitard. As a result of this variability, the B- and C-Sands recognized in the Del Amo Study Area are in direct contact and direct hydraulic communication.

3.3.2 Groundwater Flow at the Site

Recent water level data for the Site were incorporated into the Site vicinity maps shown on Sheets 3, 4 and 5. Therefore these maps are representative of the flow at the Site. Figure 3-11 is a portion of Sheet 4 (Groundwater elevations in the B-Sand) that covers the Site and the adjacent ILM site. The general direction of groundwater flow beneath the Site in hydrostratigraphic units within the Bellflower Aquitard is to the south. The direction of flow beneath the Site in the Gage Aquifer (Sheet 6) appears to be toward the east-southeast.

Hydrographs for all Site wells are shown in Figure 3-9. Hydrographs for the upgradient-most well, downgradient-most well and well with the longest record are shown in Figure 3-10. These figures illustrate a general rise in water levels that has occurred at the site since the first monitoring wells were installed.

3.3.3 Hydraulic Gradients

Water level data for two well pairs are available for the Site, WCC-1S and -1D and WCC-3S and -3D. Hydrographs for these wells shown in Figures 3-12 and 3-13 suggest that the difference in elevation between wells varies with time. The relationships between water levels indicate a general downward vertical gradient between the C-Sand and B-Sand. WCC-1S/1D shows the most consistent difference in elevation. The vertical gradient at WCC-3S/3D shows more variability than WCC-1S/1D and appears at times to be upward slightly. The estimated vertical gradients for these wells during September 1997 were:

- WCC-1S/1D -0.0089 ft/ft
- WCC-3S/3D -0.0018 ft/ft

Based on water levels collected in June 2000, the vertical gradient at WCC-3S/3D was -0.0041 ft/ft. These vertical gradients are the same order of magnitude as those measured between the B-Sand and C-Sand at the Del Amo Study Area.

3.3.4 Aquifer Properties

Slug tests and pumping tests were performed at the Site on wells WCC-1S through WCC-10S and WCC-3D during late December 1989. The results of these tests are summarized in a Table that is included in Appendix D. Analysis of the slug test results yielded estimates of hydraulic conductivity for the B-Sand that ranged from 24 to 140 gpd/ft^2 and one estimate for the C-Sand (WCC-3D) of 6.6 gpd/ft^2. Pumping test data yield hydraulic conductivity estimates of 460 to 970 gpd/ft^2 for the B-Sand. Estimates of storativity for the B-Sand ranged from 0.004 to 0.013. A description of the testing is included in Appendix D.